COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

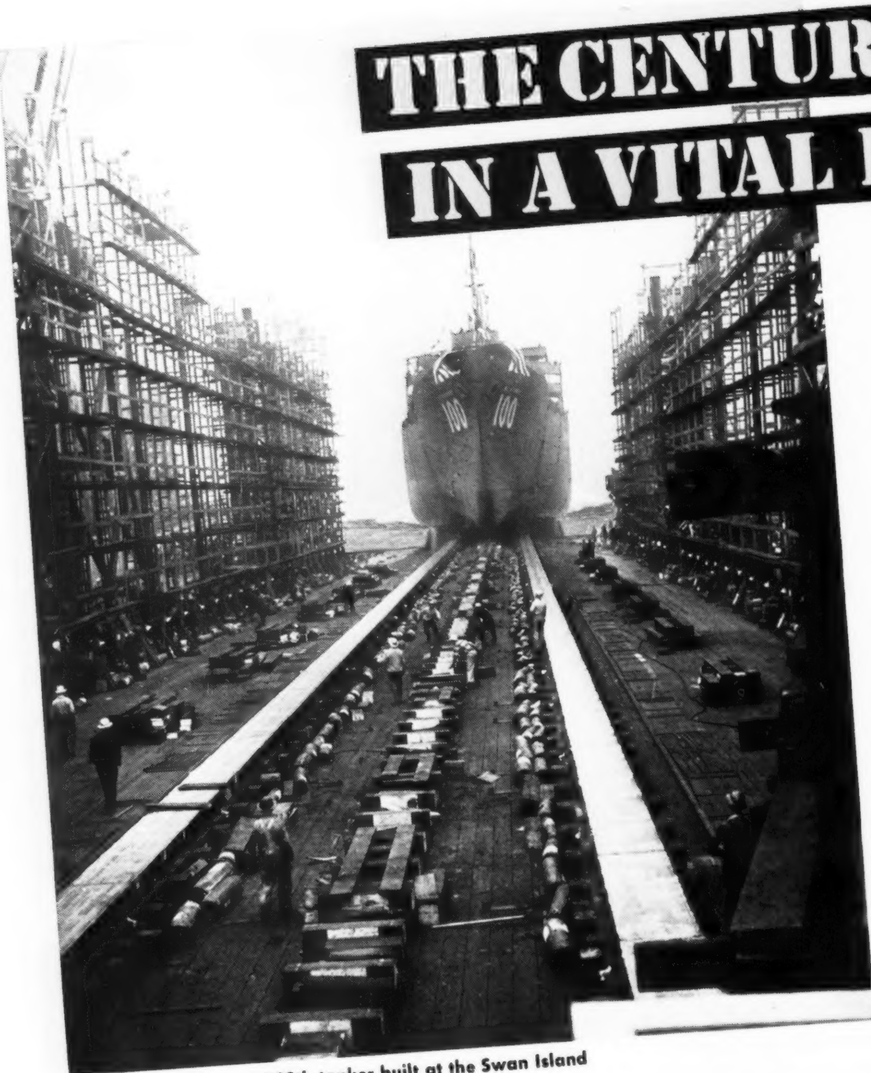
January, 1945

Interior of furnace of Port Washington boiler No. 2 (see page 32)

Port Washington Performance for 1944

Qualitative Determination of Steam-Water Mixtures

THE CENTURY MARK IN A VITAL PROGRAM



The SS. W.L.R. Emmet, 100th tanker built at the Swan Island yard of the Kaiser Co., Inc., slips down the ways.

FIGHT INFANTILE PARALYSIS

. . . the 100th Swan Island Tanker and they're all powered by C-E

THE SS. W. L. R. Emmet which recently hit the water at Portland is the 100th tanker launched at the Swan Island yard of Kaiser Co., Inc. The first of these ships, launched two years earlier, transported fuel for the invasion of Africa. In speaking of the launching of the "Emmet" Mr. Edgar Kaiser told the workers "The ships you already have delivered made possible the delivery of 1,750,000,000 gallons of gasoline to our fighting forces. That is sufficient to send over Germany 200 missions of 3,000 heavy bombers, each mission carrying approximately 2,000,000 tons of high explosive."

These ships are of the T2-SE-A1 class, the backbone of the tanker program. They have shown a speed and reliability in war service which will help to give them an edge in the peace-time scramble for maritime trade. They have also shown marked operating economy which, like their speed and dependability, is partially attributable to their C-E Marine Boilers.

The fact that all of these 100 tankers are powered with boilers designed and built by Combustion Engineering is but further evidence of the important role that C-E has been called upon to play in the creation of the country's vast war-time merchant fleet. For a substantial percentage of the cargo ships of all types — Liberties, Victories and C ships — as well as many Combat Transports, Troopships and Naval and Naval Auxiliary vessels are powered with C-E Boilers.

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200 MADISON AVENUE, NEW YORK 16, N. Y.

C-E PRODUCTS INCLUDE ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT FOR STATIONARY AND MARINE APPLICATIONS

C-E

A-850A

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIXTEEN NUMBER SEVEN

CONTENTS

FOR JANUARY 1945

FEATURE ARTICLES

EDITORIAL

DEPARTMENTS

H. STUART ACHESON, *Advertising Manager* — ALFRED D. BLAKE, *Editor* — THOMAS E. HANLEY, *Circulation Manager*

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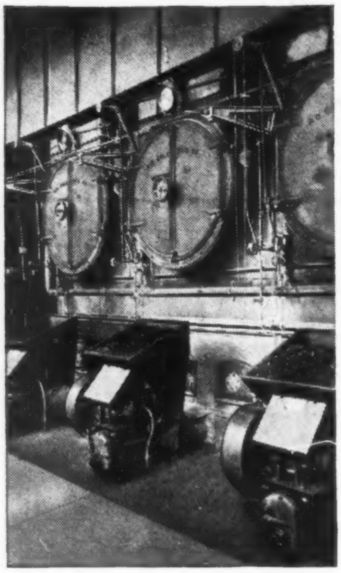
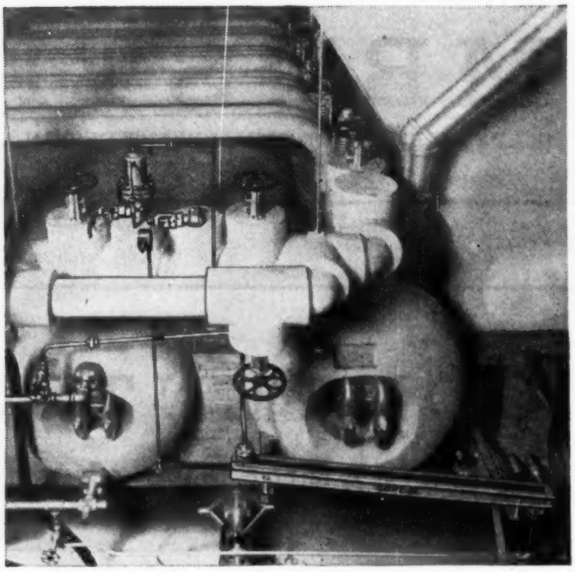
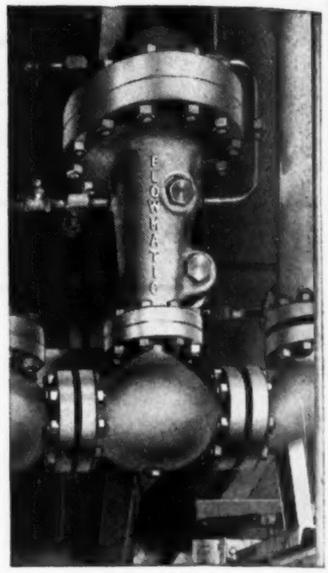


Atlanta Ice & Bottling Co., Atlanta, Georgia. 3 Copes Type OT Regulators installed on HRT Boilers operating at 100 pounds pressure.



Industrial Plant. One of two feed lines to 650-pound pressure C-E Boiler handling a peak of 150,000 pounds per hour, controlled by a Copes Type BI Regulator and Type 3-S-2 Differential Valve.



Eddy Paper Corp., White Pigeon, Mich. Direct-operated Copes Flowmatic Regulator Valve on 550-pound Badenhausen Boiler.

There's a COPES *Feed Water Regulator* FOR EVERY BOILER REQUIREMENT

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Thus a Copes assures you of individualized feed water control that is in complete agreement with the application. That's one reason why there are over 65,000 Copes Feed Water Regulators in service. For other sound reasons, write for General Catalog No. 12-41.

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EDITORIAL

LOOKING AHEAD

WHAT does 1945 hold for the field of power generation? Will the situation differ essentially from that of 1944; to what extent are new installations scheduled; will they involve any marked changes in practice; and what is the outlook concerning fuel?

These are some of the questions pertinent to this season of the year.

The downward curve of war plant construction over the past eighteen months served to make available increasing capacity in the shops of heavy equipment manufacturers which gave promise of meeting the demand for much needed replacements and deferred power plant extensions. As a result, an appreciable number of such plans were revived in both the utility and the private power plant fields. Many of these were given the "green light" by WPB before the recent turn of events in Europe brought about a sudden change in the outlook from that which prevailed in the late fall.

With all efforts now concentrated on increased war production and a consequent tightening of controls over materials and manpower, not only have reconversion plans been frozen, but new installations will require high priority to receive early consideration. The need for vast additional quantities of munitions, tanks, rockets and more ships has already earmarked much steel capacity, especially that of plate and tube mills; although the pig iron situation, aside from possible manpower restraints, will probably not be much affected. Therefore, material deliveries, except for high priority jobs, are likely to be delayed; and new plants will have to prove justification at this time.

Indications are that such extensions and replacements as are permitted will follow, with slight modifications, existing practice as to general design, steam conditions, size of units, etc., although more specific attention will be directed toward burning a wider range of fuel such as may be available in the respective localities. There promises to be wider acceptance of standardization of ratings, throttle and exhaust conditions for large turbine-generators as a result of the recommendations of the A.I.E.E.-A.S.M.E. Committee appointed for that purpose. Moreover, it is unlikely that innovations, such as the gas turbine, will find application for strictly power production in the stationary field during the present year.

It is reasonable to assume that the slight falling off in total energy demand, as noted in the fall, will again reverse in view of the increased war production schedules, at least while the present tempo on the western front continues.

Coal production during 1944, as a consequence of the high degree of mechanization in coal mining, set a new record with an output of nearly 620 million tons. This was slightly under the total demand, the difference being made up by withdrawals from storage. Indications are that, barring interruptions when the labor contract comes up for renewal the first of April, the continuing supply, amplified by further reductions in stockpiles, will be sufficient to meet all essential needs, except perhaps for certain high-grade coals required in metallurgical work. This does not mean, however, that the desired quality of coal will always be available for steam generation, and firing methods will have to be adapted in many cases to the coal obtainable. The oil and natural gas situation will probably remain about as at present.

In the realm of fuel conservation the National Fuel Efficiency Program appears to be bearing fruit and its effect is likely to be more pronounced as the present year progresses.

This appears, broadly, to be the outlook for the first half of 1945, and perhaps longer. A sudden termination of hostilities in Europe would have its effect, but the needs of devastated regions abroad would still be urgent. In fact, present commitments covering such work in the power field will require much shop capacity for many months ahead. Moreover, in the light of the misplaced optimism so prevalent last fall, it is probable that controls will continue fairly rigid until Japan is defeated.

Port Washington Performance for 1944

Again we are privileged, through the courtesy of M. K. Drewry, of the Wisconsin Electric Power Company, to report the year's performance of Port Washington Power Station together with the accumulated data since its initial operation nine years ago. Added interest attaches to the present figures inasmuch as the capacity has now been doubled and the second unit, a duplicate of the first with certain refinements, has shown an average net heat rate for the year of 10,523 Btu per kwhr.

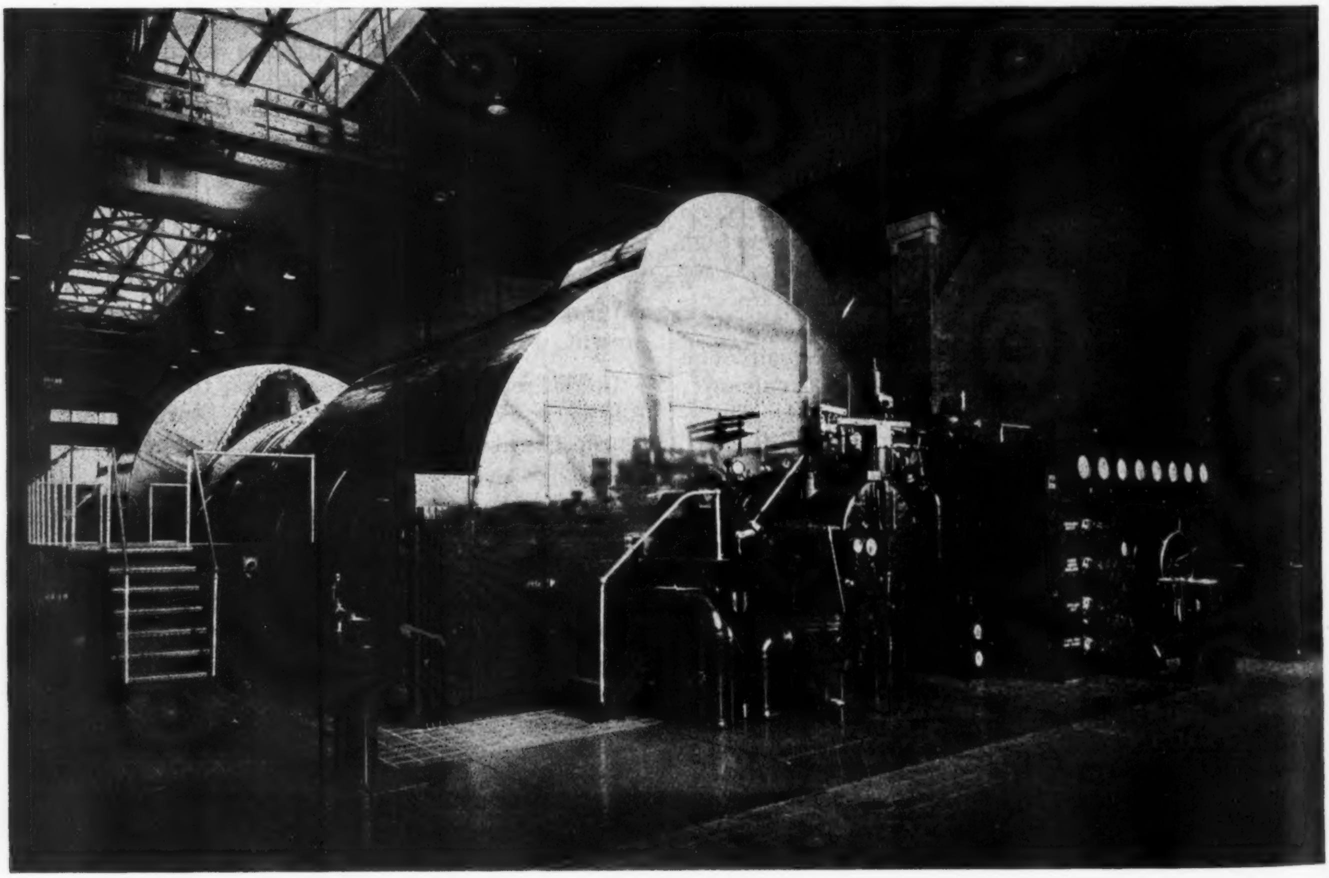
THE first unit of Port Washington Station of the Wisconsin Electric Power Company, consisting of a 690,000-lb per hr, 1300-psi, 825-F, pulverized-coal-fired boiler and an 80,000-kw turbine-generator went into service in 1936 and has achieved an outstanding record for performance in the intervening years. A second unit, duplicating the first, but incorporating certain refinements,[1] was placed in operation late in 1943. The accompanying data give the performance of both units for the respective periods during which they have been in service. From these figures it will be noted that the inherent reliability and economy sustained over the years by Unit No. 1 has not only been equalled but has been further improved upon by Unit No. 2.

Vital 1944 data for the newer unit, after two months initial operation in 1943, show it to have been in operation 90 per cent of the time, 60 per cent of which was at the rated load of 80,000 kw and that the average net heat consumption for the twelve months was 10,501 Btu per kwhr.

Recent turbine-blade trouble kept the newer unit out of service for a period approximating four per cent of the year. The duration and reasons for other outages are shown in the accompanying tabulations.

The heat consumption averaged about one per cent under Unit No. 1's best annual average of 10,596 Btu

[1] See COMBUSTION, January 1944



View, from steam end, of second 80,000-kw turbine-generator

USE AND AVAILABILITY DATA

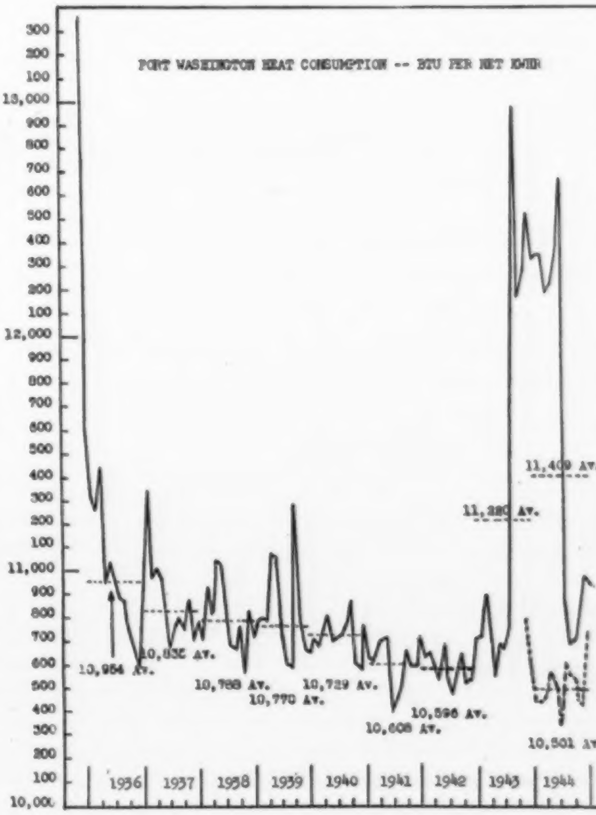
	Unit No. 1						Unit No. 2					
	1944			9-Year Average			1944			14 Months Average		
	Boiler	Turbine	Plant	Boiler	Turbine	Plant	Boiler	Turbine	Plant	Boiler	Turbine	Plant
Use Factor: Service hours / Period hours	88.1	88.1	88.1	89.4	89.3	89.3	90.4	90.3	90.3	88.5	90.0	90.0
Hourly Output Capacity Factor: Avg. hourly output / Rated hourly output	69.5	72.4	72.4	64.5	71.5	71.5	81.1	88.9	88.9	78.7	86.7	86.7
Annual Output Capacity: Annual output / Annual rated output	61.2	63.8	63.8	57.8	63.9	63.9	73.4	80.3	80.3	70.0	78.0	78.0
Annual Demand Factor: Demand hours / Annual hours	88.8	99.7	100.0	93.1	96.8	98.8	95.1	96.2	100.0	92.5	96.6	100.0
Demand Availability: Service hours / Demand hours	99.3	88.4	88.1	96.6	92.9	90.8	95.0	93.9	90.3	95.7	93.2	90.0
Annual Availability Factor: 100 — Repair hours / Annual hours	95.9	88.4	88.1	94.9	93.4	90.5	91.4	91.0	90.3	91.8	90.7	90.0

OUTPUT AND HEAT CONSUMPTION DATA

Year	Month	Net Output, Kwhr	Heat Consumption, Btu per Kwhr Gross	Aux.	Net
NO. 1 UNIT					
1944	Jan.	33,766,700	11,595	747	12,342
	Feb.	30,199,800	11,589	750	12,339
	Mar.	34,339,200	11,467	723	12,190
	Apr.	32,708,900	11,505	725	12,230
	May	32,612,900	11,594	751	12,345
	June	3,079,000	11,519	1148	12,667
	July	24,808,900	10,255	615	10,870
	Aug.	48,523,800	10,136	565	10,701
	Sept.	45,682,500	10,156	564	10,720
	Oct.	45,991,500	10,224	584	10,808
	Nov.	42,960,600	10,368	606	10,974
	Dec.	48,298,800	10,376	579	10,955
	12 Mo.	422,972,600	10,765	644	11,409
1936–44, 108 Mo.		3,824,001,400	10,298	573	10,871
1935–44, 111 Mo.		3,862,408,100	10,309	575	10,884
NO. 2 UNIT					
1944	Jan.	49,348,500	9,916	532	10,448
	Feb.	48,120,900	9,927	525	10,452
	Mar.	52,056,200	9,967	508	10,475
	Apr.	49,943,800	10,050	510	10,560
	May	36,850,100	9,965	545	10,510
	June	46,072,000	9,813	525	10,338
	July	51,793,300	10,078	535	10,613
	Aug.	48,966,900	10,046	530	10,576
	Sept.	40,670,500	10,003	537	10,540
	Oct.	39,978,900	9,926	527	10,453
	Nov.	47,696,100	9,900	518	10,418
	Dec.	24,447,000	10,088	639	10,727
	12 Mo.	535,944,000	9,970	531	10,501
1943–44, 14 Mo.		607,205,000	9,989	534	10,523

STEAM AND KILOWATT OUTPUT DATA

Output	Boiler	Turbine and Plant
UNIT NO. 1		
Total	3,711,640,000 lb steam	448,312,000 kwhr
Avg.	479,385 lb steam per hr	57,942 kw
UNIT NO. 2		
Total	4,445,897,000 lb steam	564,488,000 kwhr
Avg.	559,892 lb steam per hr	71,135 kw
BOTH UNITS		
Total	8,157,537,000 lb steam	1,012,800,000 kwhr



OPERATING PERIODS AND REASONS FOR OUTAGES—1944

Period No.	Started	Finished	Hr Run	Kwhr Generated, Millions	Outage Hours	Outage Reason
UNIT NO. 1						
63	12/27/43*	2/9/44	1,076.67	51.658	26.95	Leaking boiler tubes, No. 24 and No. 25 in 13th row above mud drum. Soot blower cutting. Forced outage
64	2/10/44	5/29/44	2,616.03	125.824	1019.85	Re-blade low pressure cylinder and spindle. General inspection of boiler and auxiliaries
65	7/11/44	12/26/44†	4,044.50	270.830		
Total	12/27/43	12/26/44	7,737.20	448.312	1046.80	
Total	11/22/35	12/26/44	71,395.78	4074.268	8355.22	
UNIT NO. 2						
5	12/27/43‡	1/11/44	381.38	26.166	7.15	Defective 22 kv disconnect on bus side of main transformer bank. Delayed forced outage
6	1/12/44	5/18/44	3,066.55	221.406	160.82	General inspection of boiler and turbine
7	5/25/44	5/25/44	6.89	0.086	7.65	Defective assembly of reheater inlet pipe joint at turbine. Forced outage
8	5/26/44	5/27/44	38.65	2.546	46.17	Inspection of turbine governor worm gears by manufacturer. Welded leak in radiant superheater, boiler
9	5/29/44	7/28/44	1,443.23	105.084	48.00	Leaking reheater tubes, boiler
10	7/30/44	9/20/44	1,248.20	90.912	262.88	General inspection of low-pressure turbine and boiler. Work on front wall air ducts of boiler
11	10/1/44	12/1/44	1,455.32	100.330	304.88	Blading failure, high-pressure turbine section. Rows 59-60-61 stationary and rotating removed and baffle installed. Delayed forced outage
12	12/14/44	12/16/44	65.70	3.322	11.00	High-pressure turbine horizontal joint sealing plug leakage
13	12/17/44	12/26/44†	229.53	14.636		
Total	12/27/43	12/26/44	7,935.45	564.488	848.55	
Total	10/27/43	12/26/44	9,213.13	639.682	1023.40	

* This operating period starting 9/3/43. Numbering of periods corrected for continuity at year-ends.
† Still in operation.
‡ This operating period started 12/6/43.

per net kilowatt-hour which has confirmed anticipations. However, the higher loading of the newer unit did not permit development of the best economy of which it is capable, for its designed heat rate increases $3^1/_2$ per cent when its load is advanced from 62,000 to 80,000 kw. The lowest monthly net heat consumption was 10,338 Btu per kwhr.

Magnetic couplings, driving the forced- and induced-draft fans have proved reliable as has also the hydrogen cooling of the generator. Early in the year frequent leaks of tube joints in the extraction heater were experienced but these have now practically ceased. Combustion has been improved by the installation of front-wall air-course baffles during outages for other reasons. Attention is called to the fact that for Unit No. 2 the boiler availability has averaged 95.7 per cent since initial commercial operation—a period of 14 months.

Unit No. 1 operated at reduced capacity during approximately half of the year as a result of turbine-blade trouble and it will be noted that re-blading the low-pressure cylinder and spindle, together with time out for general inspection, accounted for an outage of nearly 1020 hr. Thus, while the demand availability of the boiler was 99.3 per cent for the year, that of the whole unit was only 88.1 per cent. During the nine years' operation to date, this boiler has had an average demand availability of 96.6 per cent. The unfavorable loading is reflected in increased heat consumption for this unit compared with the average of previous years.

The accompanying heat consumption curve shows the economy of both units since the original starting, under all conditions of operation.

"Controlled" Forced Circulation

The following notes are intended to clarify some of the basic features of the "controlled" forced-circulation steam-generating unit which distinguish it from other forced-circulation designs.

THIS term applies to a type of forced-circulation steam-generating unit that has been installed for large capacity and high pressures in this country, as well as in smaller units, both here and abroad. A schematic arrangement is here shown. Although descriptions of such installations have appeared in print from time to time, there still seem to be certain basic features that are not too well understood by some readers.

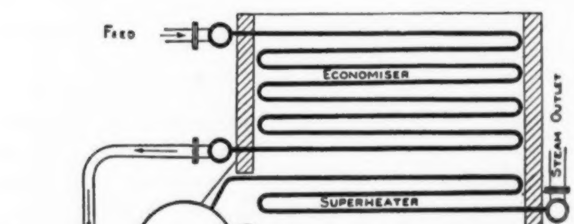
In the first place, this type is not to be confused with those forced-circulation designs, mostly foreign, in which the water is not recirculated through the steam-generating tubes and which do not employ drums.

Circulation is controlled by means of orifices at the inlets to the parallel furnace-wall tube circuits, all selected so as to provide necessary resistance for the desired distribution of flow. It is established by the use of a circulating pump, or pumps, in the downcomer circuit between the boiler drum and the entrance to the steam-generating tubes. That is, instead of relying upon thermal head to keep the water in contact with these surfaces, the circulating pump assures a positive circulation through all circuits. While the steam drum is usually located above the highest point of steam generation, this is not necessary. Where space limitations render such location undesirable, the drum can be placed where convenient. Thus, this type of unit is especially adapted to locations having restricted headroom, such as on shipboard or in certain land installations. Very low-head units can be provided with adequate and controlled circulation regardless of the operating pressure and it is immaterial whether the steam-generating tubes be vertical or horizontal in so far as concerns the circulation head.

Confusion exists sometimes, among the less informed, as to the circulating pump. Although it operates against boiler pressure, the pump head is only the differential pressure necessary to overcome the resistance through the orifices and circuits less any thermal head available. Even in a high-pressure unit the head seldom exceeds about 40 to 50 psi. The circulating pump does not take the place of the boiler feed pump, or assist it in any way. It merely recirculates the water that is not evaporated in its passage through the steam-generating tubes and, in addition, handles the feedwater delivered to the drum to replace the steam evaporated.

The circulating pump, which runs at constant speed regardless of load, handles water at a rate several times

(*Continued on page 43*)



Schematic arrangement of controlled forced-circulation boiler

Coal Sizing Recommendations

(Compiled by Combustion Engineering Company)

Equipment	Fuel	Sizing	Remarks
Traveling Grate	Anthracite	No. 3 Buckwheat (barley) All through a $^3/_{16}$-in. round mesh and not more than 20 per cent through a $^3/_{32}$-in. round mesh	(Standard anthracite sizing specifications)
Traveling Grate	Anthracite	No. 4 Buckwheat. All through a $^3/_{32}$-in. round mesh and not more than 15 per cent through a $^3/_{64}$-in. round mesh	(Standard anthracite sizing specifications)
Traveling Grate	Coke Breeze	All through a $^5/_8$-in. round mesh and not more than 50 per cent nor less than 25 per cent through a $^1/_8$-in. round mesh	Should contain 8 to 10 per cent moisture and not less than 2 per cent volatile matter. (See Note)
Traveling Grate and Chain Grate	Mid-Western Bituminous and Lignite	$^3/_4$-in. Nut and slack. Not more than 50 per cent slack through $^5/_{16}$-in. round mesh	Coal should be tempered to 15 per cent* moisture. (See Note)
Spreader	Eastern Bituminous (Friable)	$1^1/_4$-in. Nut and slack. Not more than 50 per cent slack through $^5/_{16}$-in. round mesh	(See Note)
	Eastern Bituminous (Non-friable) and Mid-Western Bituminous	$^3/_4$-in. Nut and slack. Not more than 50 per cent slack through $^5/_{16}$-in. round mesh	(See Note)
Underfeed Stokers: Multiple-Retort, Type E, Skelly and Low Ram	Eastern Bituminous (Friable)	2-in. Nut and slack. Not more than 50 per cent slack through $^5/_{16}$-in. round mesh	(For Multiple Retort—See Note)
	Eastern Bituminous (Non-friable) and Mid-Western Bituminous	$1^1/_4$-in. Nut and slack. Not more than 50 per cent slack through $^5/_{16}$-in. round mesh	(For Multiple Retort—See Note)
Skelly	Anthracite	No. 2 Buckwheat (rice). All through a $^5/_{16}$-in. round mesh and not more than 15 per cent through a $^3/_{16}$-in. round mesh	
Pulverizers	All Coals	$^3/_4$-in. Nut and slack	

NOTE: Fuel to be delivered across stoker hopper without segregation.

* Certain western and mid-western coals (certain Iowa coals, for example) may require 20% moisture or more for proper tempering.

Qualitative Determinations of Steam-Water Mixtures

By T. RAVESE and C. G. R. HUMPHREYS

Combustion Engineering Company, Inc.

The feature of this heat-exchanger type of calorimeter, devised for determining the proportion of steam in steam-water mixtures of boiler circuits, is that the sample does its own cooling and it is therefore necessary only to measure the temperatures at three points and apply these readings to a simple equation.

QUALITATIVE measurements of steam-water mixtures in modern high-pressure boiler circuits are important parts of boiler circulation studies. Such measurements in heated tubes, in conjunction with tube velocity data, establish the overall heat absorption of the tube. The calorimeter here described was primarily designed to detect small amounts of steam in downcomers to furnace water-wall tubes, but it also has been used to measure the quality of steam-water mixtures in heated boiler tubes.

The arrangement of this heat-exchanger type of calorimeter is shown schematically in Fig. 1, the assembly consisting of three double-pipe heat exchangers, each containing the heat-transfer surface represented by the dimensions given in the tabulation on Fig. 2. The heat exchangers are designated as primary, secondary and tertiary units, and the flow circuits of the fluid sample and the cooling water are represented by the solid and broken lines and arrows, respectively, in Fig. 1.

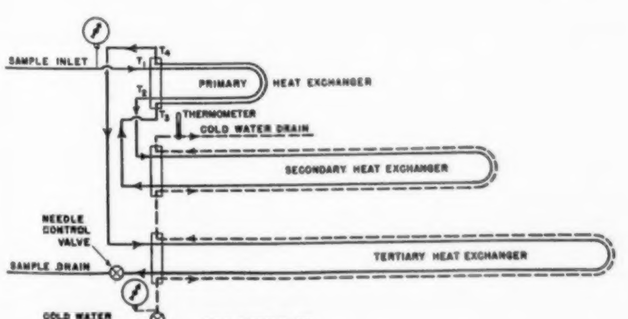
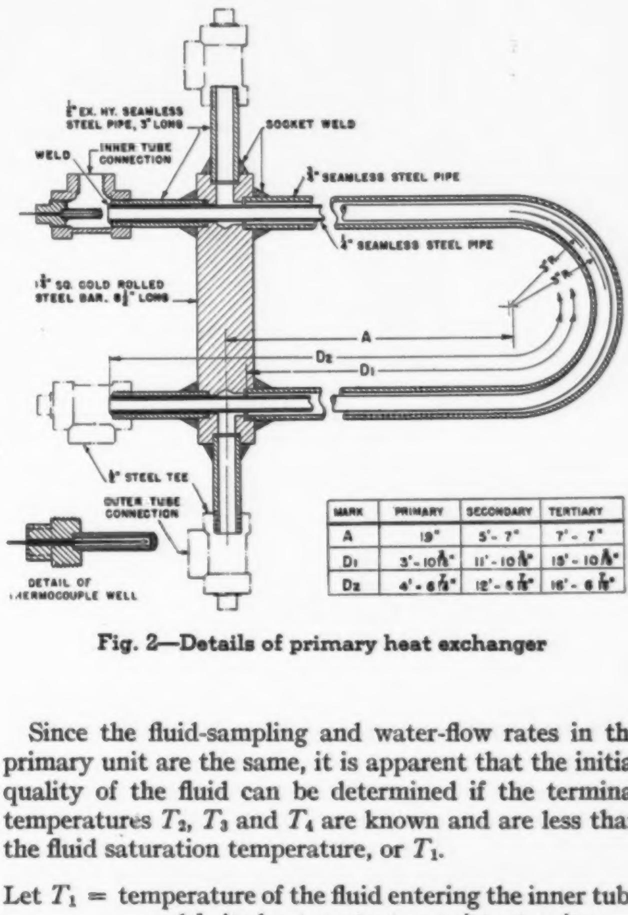


Fig. 1—Diagram of flow circuits and heat-exchanger units

A continuous sample of the fluid, which is a mixture of water and steam, is withdrawn from the tube through a standard sampling nozzle and flows through the inner pipe of the primary unit. The sample gives up heat to water counterflowing at the same flow rate through the annular opening between the inner and the outer tubes of the heat exchanger. This cooling water is the continuous sample which has been sub-cooled by an external source of water in the secondary and tertiary units. Hence, weights of the mixture or the cooling water do not enter into the calculations. The heat-exchanger units operate at boiler pressure and the sample flow rate is controlled at the outlet end of the tertiary unit. The fluid sample is cooled to about 175 F, or less, at the discharge point.



MARK	PRIMARY	SECONDARY	TERTIARY
A	19"	5'- 7"	7'- 7"
D1	3'-10 3/16"	11'-10 3/16"	15'-10 3/16"
D2	4'-6 7/16"	12'-5 7/16"	16'-6 7/16"

Fig. 2—Details of primary heat exchanger

Since the fluid-sampling and water-flow rates in the primary unit are the same, it is apparent that the initial quality of the fluid can be determined if the terminal temperatures T_2, T_3 and T_4 are known and are less than the fluid saturation temperature, or T_1.

Let T_1 = temperature of the fluid entering the inner tube and h_1 its heat content, consistent units

T_2 = temperature of the water leaving the inner tube and h_2 its heat content

T_3 = temperature of the water entering the outer opening and h_3 its heat content

T_4 = temperature of the water leaving the outer opening and h_4 its heat content.

Then $(h_1 - h_2) = (h_4 - h_3)$ and $h_1 = (h_4 - h_3) + h_2$.

The values of h_2, h_3 and h_4 are readily determined from the liquid temperatures T_2, T_3, T_4, because the calorimeter

operates at boiler pressure minus a negligible pressure loss. If h_1 is equal to, or less than, h_f (the heat of the saturated liquid at the sampling location) then no steam is present in the fluid sample. Similarly, if h_1 is greater than h_f then $h_1 - h_f$ is the heat available for vaporization and the quality of the fluid is given by $(h_1 - h_f)/h_f$.

Construction and Installation

A working drawing of the heat-exchanger unit suitable for pressures up to 2000 psi is shown in Fig. 2. It is shown with thermometer, or thermocouple, inserts which are necessary only on the primary unit. Surface dimensions of the primary, secondary and tertiary units are given in Fig. 2. The heat-transfer surface consists of a section of $^1/_4$-in. seamless steel pipe drawn inside of a section of $^3/_4$-in. seamless steel pipe, in the form of either loops or coils. These are bent to shape and fitted into a $1^3/_4$-in. steel square bar drilled as shown for the tube connections. The inner tube connections extend through the steel bar and the outer tube connections are made at right angles to the tube through two right-angle holes in the square bar.

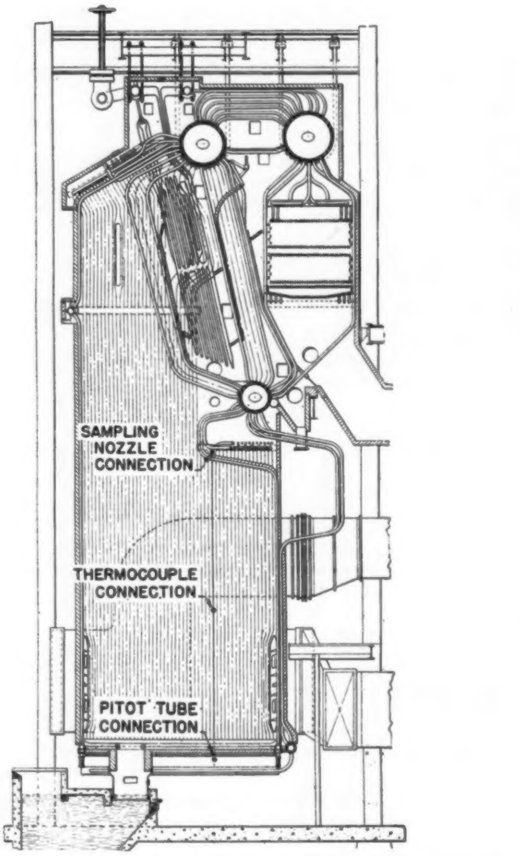


Fig. 3—Application to walls of large high-pressure boiler

Each external connection of the primary heat exchanger is fitted with a $^1/_2$-in. pipe tee which has a thermocouple well in the run of the tee. This well consists of a $^1/_4$-in. seamless steel tubing, $^1/_{20}$ of an inch thick, socket-welded to a $^1/_2$-in. plug containing a $^3/_{32}$-in. drill hole. The tubing length should be sufficient so that the lower portion will extend into the fluid stream at the side outlet of the tee. A detail of the thermocouple well is shown at the lower left in Fig. 2. Duplex glass-insulated No. 24 Awg calibrated iron constantan thermocouple is used for the temperature measurements.

The fluid sample connection to the primary heat exchanger must be of ample size, flexible, and its length a minimum. This is necessary to minimize the pressure loss and radiation and also to allow for movement of the boiler tube or downcomer. The secondary and tertiary units are mounted at any convenient location as they are not involved in the measurements. The fluid sampling lead, and the primary unit, are carefully insulated with "Hi-temp" insulating cement. A needle control valve is provided at the outlet of the heat exchanger to regulate the fluid sampling rate. A pressure gage is mounted at the cooling water inlet to the tertiary heat exchanger and a thermometer is inserted at the cooling-water outlet for proper regulation of the cooling-water supply.

Operation and Test Results

The heat-exchanger unit must be in service about forty-five minutes before taking calorimeter data. During this time the cooling-water inlet pressure is maintained constant and the fluid sample needle valve adjusted for a flow of about 250 lb per hr. The terminal temperatures of the primary heat exchanger are observed with a semi-precision potentiometer. These measurements are repeated until several duplicate sets of temperatures are obtained. The boiler operating conditions should be constant during the measurements and a record made of the boiler rating, fluid pressure, feedwater temperature and drum water level.

A typical set of observed data and calculations for downcomer fluid samples is given in Table 1 for a boiler operating at 1400 psi.

TABLE 1

Boiler steam flow, M lb per hr	477	475	475	480
Pressure gage reading, fluid sampling point, psi	1425	1395	1420	1400
Feedwater flow, M lb per hr	485	485	485	495
Feedwater temp., inlet to econ., F	418	410	410	400
Feedwater temp., outlet of econ., F	510	508	510	503
Drum water level, inches below centerline drum	12	12	12	$11^1/_2$
Downtake sampling location, No.	1	2	3	4
Primary heat-exchanger temperatures				
T_1, F	589.5	587	589.5	588.5
T_2, F	516	524	526.5	521
T_4, F	354.5	367	375.5	365.5
T_3, F	261	289	296	279
Heat content, Btu per lb				
h_f	602	598	602	601
h_1	603	596	601	602
h_2	507	516	519	513
h_4	329	341	350	340
h_3	233	261	268	251
$h_1 - h_f$	1	−2	−1	1
h_{fg}	570	575	570	574
Steam quality, fluid, per cent by weight	0.18	0.00	0.00	0.17

The above data indicate that fluid samples from locations 1 and 4 contained a trace of steam.

It is noted that the fluid temperature T_1 is less than the saturation temperature obtained from the pressure gage readings (locations 1 and 4). This should not be disturbing as the accuracy of the pressure gages was doubtful. Furthermore, the gages were graduated in 25-lb divisions and 10 lb is equivalent to one degree at 1400 psi pressure.

Fig. 3 represents test equipment located on a wall tube in a boiler operating at 1350 psi, 925 F steam temperature, rated at 615,000 lb of steam per hour normal capacity.

A short, 3-in. O.D. finned wall tube was equipped with a pitot tube of the type described in COMBUSTION, October 1944, p. 43. This pitot tube, located below the

furnace floor, measured velocity of entering water before any steam was generated in the wall tube.

About 15 feet along the tube there was a chromel-alumel thermocouple of rugged construction, as described in COMBUSTION, December 1944, p. 53. This couple measured the wall tube's surface temperature at this point.

Situated near the upper header and just outside the furnace was a standard A.S.M.E. Steam Sampling Nozzle connecting to a heat-exchanger type calorimeter as here described.

Fig. 4 is a graphic record of this wall tube's function before, during and after a period of furnace deslagging. After prolonged operation at 580,000 lb of steam per

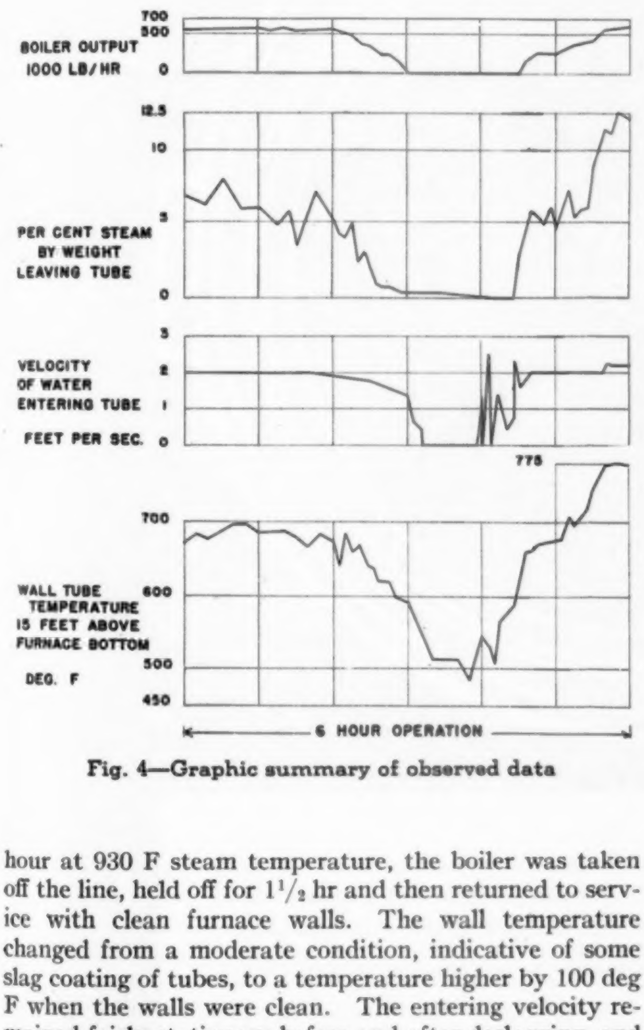


Fig. 4—Graphic summary of observed data

hour at 930 F steam temperature, the boiler was taken off the line, held off for $1^1/_2$ hr and then returned to service with clean furnace walls. The wall temperature changed from a moderate condition, indicative of some slag coating of tubes, to a temperature higher by 100 deg F when the walls were clean. The entering velocity remained fairly stationary before and after deslagging, and the occasional spurts upward from zero, at 10:50 to 11:30 coincided with intermittent gas or coal firing before the boiler came back on the line. The quality of the mixture leaving the tube, the chief objective here, is comparable with falling and rising boiler rating.

Fig. 4 is a graphic summary of some observed data and Table 2 gives all necessary readings and calculated qualities at four test points.

In COMBUSTION, May 1941, p. 51, there was an article on "The Flashing Calorimeter" by A. A. Markson and Y. A. Olson. This instrument is referred to as a check or alternate method of measuring steam quality.

TABLE 2

Elapsed time (see Fig. 4), hr	0	3	$4^2/_3$	6
Boiler steam flow, M lb per hr	570	0	220	620
Pressure gage reading, fluid sampling point, psi	1325	1275	1215	1350
Primary heat exchanger temperatures				
T_1, F	580	574	568	581
T_2, F	429	386	410	416
T_4, F	338	317	329	359
T_3, F	118	102	113	96
Heat content, Btu per lb				
h_f	589	581	573	590
h_1	631	587	608	662
h_2	407	366	387	393
h_4	310	291	302	333
h_3	86	70	81	61
$h_1 - h_f$	42	6	35	72
h_{fg}	594	604	615	590
Steam quality, fluid, per cent by weight	7.1	1.0	5.7	12.2

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1944 Water Tube		1943 Water Tube		1944 Fire Tube		1943 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	36	226,537	11	64,189	24	31,701	16	18,888
Feb.	39	256,942	32	164,800	28	43,341	237	146,834
Mar.	47	229,121	31	147,937	44	53,893	16	24,293
Apr.	80	448,646	95	361,746	50	68,430	21	32,392
May	74	392,347	127	683,052	49	66,722	9	14,106
June	65	286,486	163	679,306	70	92,621	25	41,073
July	78	457,442	31	222,253	56	67,126	18	9,549
Aug.	113	448,161	51	311,448	52	69,832	30	38,797
Sept.	123	532,895	40	145,587	52	68,783	33	40,599
Oct.	119	603,687	103	301,574	65	79,289	26	34,542
Nov.	138	490,233	52	273,488	68	82,182	13	19,470
Jan.–Nov. incl.	912	4,372,497	736	3,355,380	558	723,920	444	609,551

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to Nov. (incl.), 1944, 33,454,000 lb per hr; in 1943, 32,097,000 lb per hr.

Marine Boiler Sales

	1944 Water Tube		1943 Water Tube		1944 Scotch		1943 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	49	273,879	597	2,185,483	—	—	1	1,080
Feb.	96	507,658	31	102,404	30	9,000	—	—
Mar.	70	226,166	156	430,841	38	9,700	1	2,565
Apr.	44	209,906	19	85,244	48	14,405	2	5,130
May	94	443,130	594	4,985,280	37	11,100	3	6,401
June	193	1,003,435	895	4,241,507	32	13,100	1	2,565
July	113	390,964	386	1,852,389	22	8,120	1	2,565
Aug.	182	811,978	729	3,320,329	26	11,983	4	7,730
Sept.	14	23,768	74	321,124	22	9,781	2	5,130
Oct.	52	67,560	39	166,373	36	16,085	2	5,130
Nov.	19	164,458	84	343,595	23	11,262	1	988
Jan.–Nov. incl.	926	4,122,902	3,604	18,034,569	314	114,536	18	39,284

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to Nov. (incl.), 1944, 51,875,000 lb per hr; in 1943, 180,824,000 lb per hr.

†Mechanical Stoker Sales

	1944 Water Tube		1943 Water Tube		1944 Fire Tube		1943 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	35	13,982	131	46,948	147	20,761	457	31,623
Feb.	35	18,437	106	34,685	156	22,495	575	83,673
Mar.	56	20,128	114	48,367	142	5,660	571	77,729
Apr.	58	21,680	96	32,251	153	21,923	432	64,022
May	54	20,920	96	39,640	222	30,457	414	57,889
June	57	21,055	118	61,415	290	35,592	296	49,760
July	80	28,543	98	50,992	287	41,550	379	52,680
Aug.	115	35,077	68	31,377	358	48,532	446	62,732
Sept.	110	34,586	49	18,911	291	35,868	446	55,496
Oct.	90	29,926	159	53,382	322	43,722	391	54,477
Nov.	120	33,489	57	21,619	242	29,799	247	33,495
Jan.–Nov. incl.	810	277,823	1,092	439,587	2,610	336,359	4,654	622,778

† Capacity over 200 lb of coal per hour.

*Silica Deposition in Steam Turbines**

By F. G. STRAUB and H. A. GRABOWSKI

Engineering Experiment Station, University of Illinois

Laboratory and power-plant tests have been conducted to determine the cause of silica deposition in steam turbines. The tests indicate that the silica leaves the boiler as vaporized silicic acid which later crystallizes on the blades in the lower pressure stages of the turbine. When the silica in the steam is below 0.1 ppm, no appreciable deposits are found in the turbines. Two methods of preventing deposits are suggested; (1) maintain the silica in the boiler water below 5 ppm; (2) remove the silica from the steam by scrubbing with a pure grade water.

IN recent years almost parallel with the increase in steam pressures, a new type of deposit appears to be forming in steam turbines. When the upper steam pressures were about 600 psi, the deposits which formed were water soluble and could readily be removed by a water wash. The average type of deposit was mainly the sodium salts such as chlorides, sulphates and silicates together with sodium hydroxide.

With increase of steam pressures to around 1400 psi and the installation of topping turbines, the type of deposit formed in the high-pressure end of the topping turbine is similar to older types and is water soluble. However, at the low-pressure end of the topping unit and in the low-pressure machines, a deposit insoluble in water is formed. This deposit consists mainly of silica (SiO_2) in its various crystalline forms. It may be removed by mechanical cleaning or by washing with sodium hydroxide.

It has been rather difficult to give a logical explanation of how the silica present in the boiler water as sodium silicate is transported through the high-pressure turbine and deposited on the low-pressure machines as a crystalline silica. Splittgerber[1] presented experimental data which showed that silica could be vaporized from silicic acid in appreciable amounts at 100 atm steam pressure. These results showed that the silica in the steam increased with increasing silica concentration in the boiler water. As the pressure increased, the silica in the steam increased. The addition of NaCl, Na_2SO_4, NaOH and Na_3PO_4 to the boiler water caused the silica in the steam to decrease. The values given by Splittgerber were not readily correlated with data available from boiler operation.

If this work of Splittgerber could be carried further and additional data collected as to the feasibility of silica leaving the boiler as vaporized silicic acid, a logical explanation would be available to account for the deposition of the silica crystals in the low-pressure turbines. If silicic acid has an appreciable vapor pressure at higher steam pressures, the sodium silicate in the boiler would hydrolyze, and silicic acid would be present in the steam in amounts depending upon the mol concentration of the silicic acid in the boiler water and the vapor pressure of silicic acid at that temperature. Since the concentration in boiler water of the silicates is very low, the amount in the steam would be much lower than that corresponding to the true vapor pressure of silicic acid. When superheated steam containing this amount of silicic acid is dropped in pressure and temperature, a point will be reached where the silicic acid in the steam becomes greater than the amount corresponding to the vapor pressure of solid silicic acid. When this point is reached, the silicic acid in the steam will leave the superheated steam and deposit as a hydrated-silica deposit. If the steam reaches the saturation point before this occurs, the silicic acid being slightly soluble in water will be dissolved in the condensate and no deposit will form.

Since this appeared to be a logical approach to this problem, laboratory work parallel with power-plant tests was inaugurated in order to see if Splittgerber's method of approach was applicable to the problem of silica blade deposits. The laboratory work was conducted along two lines as follows:

1. The relationship between silica in the steam and silica in the boiler water at various pressures.
2. The relationship between solid silicic acid and the silica in the steam at various pressures and temperatures.

The power-plant tests were conducted to find the following:

1. The relationship between the silica in the steam and silica in the boiler water.
2. The changes occurring in the silica in the steam as it passed through the turbines.

The silica in the steam cannot be considered as being mechanically carried into the steam as the soluble silicate occurring in the boiler water. If it were being mechanically carried, the salts in the steam entering the superheater should be present in the same relative proportions as they are in the boiler water. Thus, with a total dissolved-solids content of 500 ppm and SiO_2 30 ppm in the boiler water, a steam having 0.30 ppm of SiO_2 should have 5 ppm of soluble solids present, if the silica were present as a mechanical carry-over from the boiler water. Since the total solids in the average steam, as indicated by conductance measurements and evaporation tests, are well below 1 ppm, the presence of such a large percentage of silica would indicate that there was a selective concentration of silica in the steam.

If the silica were being vaporized as silicic acid, such

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*Excerpts from a paper before the 1944 A.S.M.E. Annual Meeting and based on data from research conducted at the University of Illinois in cooperation with the Utilities Research Commission of Chicago.

[1] "The Volatility of Silicic Acid," by A. Splittgerber, *Archiv. fur Warmewirtschaft*, vol. 22, 1941.

concentrations could occur in the absence of mechanical carry-over. In order to obtain data as to the possibility of such vaporization, tests were started using a high-pressure laboratory boiler, designed so as to prevent any mechanical entrainment of boiler water in the steam. It also prevented any condensation of steam prior to leaving the boiler and thus gave a representative sample of the steam in equilibrium with the boiler water.

Discussion of Laboratory Tests

The laboratory tests showed that sodium silicate in boiler water at steam pressures above 700 psi will liberate silica, presumably as silicic acid, in appreciable amounts without mechanical entrainment of boiler water. This amount increases rapidly with pressure increase. It also increases as the pH value of the boiler water is decreased.

When superheated steam is passed over solid silicic acid at various pressures and temperatures, definite amounts of silica are present in the steam corresponding to the temperature and pressure. No silica occurs in the superheated steam when it is passed over solid sodium silicate ($NaO \cdot SiO_2 \cdot 5H_2O$ before being superheated).

These results indicate that solid silicic acid has an appreciable vapor pressure at temperatures above 400 F. When the silica is present in solution in the boiler water as sodium silicate, the mol concentration of the silicic acid is very low, consequently, the vapor pressure over the solution does not become appreciable until pressures around 1200 psi are reached. The vapor pressure of the silicic acid over the boiler water will be low due to the small mol concentration and the high pH value of the boiler water. Thus, the concentration in the steam will be much lower than that corresponding to the true vapor pressure of the solid silicic acid at the higher temperature and pressure in the superheater and the higher pressure end of the turbine. However, as the temperature and pressure of the steam drop, as it passes through the turbine, a point will be reached where the silicic-acid concentration in the steam becomes greater than the silicic-acid content corresponding to the vapor pressure over solid silicic acid. When this occurs, silicic acid will deposit. Thus, the higher the silica content of the steam leaving the boiler, the higher up in the turbine the deposits will start forming, and the greater the amount of deposit which will form in the turbine. If the silica in the boiler water is kept below certain values, the deposit forming in the turbines should be negligible.

Power-Plant Tests

Studies were made in three power plants having boilers operating around 1250 psi to determine the ratio between the silica in the steam and that in the boiler water. All three of these plants use evaporator makeup, have phosphate treatment, and use fresh water for surface condensers.

In plant *A*, the pH value of the boiler water was between 10.9 and 11.1. Daily analyses for silica were made on the superheated steam from each of the three boilers and on the combined steam from the main header. Silica was also determined in the boiler water from each boiler.

The silica in the boiler water averaged 8 ppm with a minimum of 4 ppm and a maximum of 13 ppm. The silica in the steam averaged 0.05 ppm with a minimum of 0.02 ppm, and a maximum of 0.10.

The ratio of the silica in the steam to that in the boiler water was between 0.5 and 0.8 per cent. The specific conductance of the degassed steam was about 1 micromho.

In plant *B*, the pH value of the boiler water was between 10.7 and 11.2. Daily analyses for silica were made in a similar manner to plant *A*.

The silica in the boiler water averaged 9 ppm with a minimum of 5 ppm, and a maximum of 14 ppm. The silica in the steam averaged 0.05 ppm with a minimum of 0.03 ppm, and a maximum of 0.10 ppm. The ratio of the silica in the steam to that in the boiler water was between 0.5 and 0.7 per cent. The specific conductance of the degassed steam was about 1.2 micromho.

In plant *C* when the pH value of the boiler water was between 11.0 and 11.3, the silica in the steam was between 0.01 and 0.05 ppm. The boiler water had a silica content between 2 and 5 ppm. This gave a ratio of silica in the steam to that in the boiler water around 0.8 per cent with a maximum of 1 per cent.

In plants *A* and *B*, no data are available on the silica content of the low-pressure steam or the condensate. This was due to the fact that the deposits forming on the low-pressure units were of a small order of magnitude. Thus, in plant *B*, the low-pressure unit at the end of 2 years when examined on scheduled outage showed a small amount of deposit. However, this soft and easily removed deposit was forming in the temperature range from 400 to 250 F. It contained from 30 to 71 per cent SiO_2. The silica was present as cristobalite and chalcedony, both crystalline forms of silica. The rest of the deposits consisted mainly of iron oxides (red and black).

In plant *C*, prior to the time when the values reported were obtained, much difficulty was experienced with turbine-blade deposits in the low-pressure units. At the time these deposits were forming the silica content of the boiler water varied between 10 and 40 ppm. The silica in the steam leaving the boilers varied between 0.1 and 0.4. The steam condensate from the low-pressure machines contained about 0.1 to 0.2 ppm SiO_2. This showed a loss of up to 0.2 ppm SiO_2 in the steam passing through the low-pressure units, a definite indication of silica deposition in the units. At the same time, the stage pressures indicated deposits were forming. When the conditions of operation were changed so that the silica in the boiler water was kept below 5 ppm, the silica in the high-pressure steam was the same as that in the condensate from the low-pressure units. This indicated no silica deposition in the units. At the same time, the stage pressures showed no indications of deposits forming.

From the study made in this plant, it was concluded that, when the silica in the steam became higher than 0.1 ppm, there was a probability that deposits would form in the low-pressure turbines. When this value has been kept below 0.05 ppm, the units have operated over $1^{1}/_{2}$ years with no indications of deposits forming.

During these plant tests, it was noticed that the silica content of the boiler water in plants *A*, *B* and *C* (during the days of higher silica content) increased whenever the boilers came on the header after being on bank. At the same time the silica content of the steam also increased. These values returned to average shortly after the boiler was in normal operation. This appears to be connected with so-called "hideout."

Prevention of Silica Blade Deposits

The plant tests indicated that when the silica in the boiler water is kept below 5 ppm and the pH of the boiler water around 11, no appreciable silica deposits form in the turbines. When the silica in the steam becomes greater than 0.1 ppm deposits will form.

This indicates that, in order to prevent this type of deposit, it is essential that the silica in the steam be kept very low. This may be accomplished either by keeping the silica in the boiler water very low or by removing it from the steam before superheating.

Studies have been made in the laboratory relative to reducing the soluble silica in the boiler water by the addition of chemicals which will precipitate the silica as an insoluble sludge.

Steam was passed through the solution in a bomb, the procedure being to add sodium silicate and NaOH to get the desired silica and pH value of the solution in the bomb. Known amounts of $MgSO_4 \cdot 7H_2O$ (Epsom salts) were put in solution and pumped into the bomb. The steam and a sample of the bomb solution were then analyzed. This procedure was followed until a constant low value for silica was reached. The addition of the magnesium reduced the soluble silica from 82.5 ppm to around 2 ppm. Since Epsom salts is acidic, it was necessary to add an equivalent amount of sodium hydroxide in order to maintain the desired pH value. The soluble silica remained around 2 ppm even after an excess of magnesium salt had been added. These results indicate that it is possible to reduce the soluble silica to around 2 ppm by the addition of magnesium and that the silica is retained in the sludge.

Since the concentration of the silica in the steam is a function of the silica concentration of the solution in contact with the steam, the silica in the steam could be reduced to a low value by bringing the saturated steam in contact with a water having a very low silica content. This would involve the scrubbing of the saturated steam with a fairly pure water low in silica. Such a procedure should also reduce mechanically entrained boiler water to a low value and stop soluble as well as insoluble deposits.

"Controlled" Forced Circulation

(*Continued from page 34*)

the rate of steam generation, this rate depending upon the circulation ratio for which the unit is designed. The circulation ratio is defined as the ratio of the weight rate of water fed to the steam-generating tubes to that of steam generation. It is customary to design for a ratio of three to five at maximum load.

Because of the orifice features mentioned, it is a simple matter to design for different circulation ratios in different parts of the unit, as conditions dictate. For instance, furnace-wall tubes which are subjected to high and variable rates of radiant heat absorption, as distinguished from convection-generating surface in contact with cooler gases, will require a higher circulation ratio. Moreover, adjustment of the orifices in the field affords a ready means of changing the circulation ratios in individual circuits where necessary.

In the Combustion Engineering Controlled Forced-Circulation boiler, the circuits comprising the steam-generating surface may be individual tubes, or elements made up of two or three tubes joined into a single tube at the inlet end. An element comprising two tubes in parallel is designated as bifurcated and one comprising three tubes in parallel as trifurcated.

Use of orifices in conjunction with forced circulation permits a control of water distribution that is not possible with natural circulation and makes it possible to design a forced-circulation unit to operate with a lower circulation ratio than a natural-circulation boiler.

Advantages of Small Tubes

The head available for circulation in a natural-circulation boiler is that created by the difference between the density of the fluid in the down-flow and that in the up-flow circuits, minus the loss of head caused by fluid friction, turbulence and acceleration. If too much head is used up in fluid friction and turbulence, that available for circulation will be insufficient and the circulation ratio will be low. This explains why smaller tubes can be employed in a forced-circulation boiler, particularly where the additional head required to overcome fluid friction and turbulence and maintain required velocities is supplied by the circulating pump. For the same reason a small orifice, involving a relatively high pressure drop can be employed in each parallel circuit without the operating head of the circulating pump exceeding 40 to 50 psi.

One advantage of being able to employ small diameter tubes is that they are thin-walled; hence result in less temperature drop through the wall and lower hot-face temperature. Also, with small furnace tubes in a forced-circulation boiler higher fluid velocity is obtained than with large tubes, for the same circulation ratio; or, conversely, the same velocity could be maintained with a lower circulation ratio for small tubes. They are more flexible; there is saving in weight over larger tubes; and they can be more readily bent to fit around burners, soot blowers, doors, etc. Furthermore, inasmuch as the small tubes can be readily forged to form bifurcates or trifurcates, one orifice may be used to serve two or three tubes and the number of connections to distributing headers is reduced. This, in turn, reduces the number of orifices, strainers and closure plugs, and simplifies header construction.

TVA Report

In the annual report of the Tennessee Valley Authority for the fiscal year ending June 30, 1944, a total output of over 10 billion kilowatt-hour sales were shown, representing a gross return of more than 35 million dollars. The net profit reported amounted to approximately 14 million dollars, after deducting operating expense, depreciation, and payments to numerous states, counties and municipalities in lieu of taxes, but without charging interest on the 395 million dollars expended on TVA power facilities to date.

Additions to installed capacity during the fiscal year were 254,000 kw which brought the total capacity of the system up to nearly 2 million kilowatts.

The increase in load of 8 per cent over that of the preceding year was largely due to demand for power for war production, which accounted for about three-fourths of the total output for this period.

Selection of Traveling Crane Equipment

FOLLOWING are excerpts from a paper by **R. J. Wadd** and **F. M. Blum,** of Harnischfeger Corp. at the recent Materials Handling Machinery Manufacturers Conference held at the Westinghouse Works, East Pittsburgh. The paper dealt with several classes of cranes for different services, but reference here will be made only to those for power-house duty in which the principal requirements are slow speed, occasional use, long life and two to five full-load lifts per hour.

Suggested operating speeds for such service are as follows:

Capacity	Hoist Speed	Trolley Speed	Bridge Speed
3	33	125	250
5	25	125	250
7 1/2	25	125	250
10	25	125	250
15	20	125	250
20	15	125	250
25	14	125	250
30	12	125	250
35	12	100	200
40	11	100	200
45	10	100	200
50	10	100	150
60	10	100	150
75	9	75	150
85	8	75	150
100	8	75	150
125	6	75	100
150	5	50	100
175	4	50	100
200*	4	35	100
250*	3	35	100
300*	3	35	100

* Double trolley crane.

Motors

All d-c motors should be totally enclosed and be series wound. They should be provided with anti-friction bearings and have a large diameter shaft with a tapered end on which is mounted the brake wheel.

Where alternating current is employed, slip-ring or wound-rotor motors are generally used, since the squirrel-cage type does not provide good speed regulation. As in the case of the d-c motor it should employ grease-lubricated anti-friction bearings and have a tapered shaft extension for easy removal of the brake wheel. The stator laminations and windings should be well anchored so that they cannot work loose under the reversals of service to which the motor is subject. It is also essential that the rotor be well balanced and that brushes and slip-rings be of high quality bronze, to prevent pitting under plugging service.

Wound-rotor induction motors, as usually applied to overhead traveling cranes, are built with the open type rated 30 min, 50 deg; the enclosed type rated 30 min, 55 deg; and the totally enclosed, fan-cooled type rated 1 hr, 55 deg. While the open motor is cheaper, the totally enclosed type will offset the difference through less maintenance and prolonged life.

When selecting a hoist motor, thought must be given to the length of the lift. If this is great a 30-min rated motor must be selected rather than one of 15-min rating.

Bridge and trolley motors are selected on the basis of determining the running horsepower required. Allowance must be made for rolling and flange friction, condition of the track and acceleration.

Speed regulation of power-house cranes is very essential and the proper selection of motors is equally as important as the selection of control.

Brakes

Various types of brakes are used on overhead traveling cranes, such as a-c, d-c, electric-magnet brakes, hydraulically or mechanically operated foot brakes, constant drag brakes and combination electric-hydraulic brakes. Selection is dependent upon the class of crane (as to service), the horsepower of the motor and the type of control employed. In general, all brakes must possess one inherent characteristic; they must be able to stop the motion of the crane under all weather and service conditions, within its rated capacity. Direct-current operated brakes equipped with series-wound coils should release at 40 per cent of the rated current of the hoist motor, and alternating-current brakes at 80 per cent. When selecting brakes for the hoist motion of the cranes for service such as in a power plant they should be chosen on the basis of 150 per cent torque of the nameplate rating of the hoist motor, when used in conjunction with d-c dynamic lowering control as well as a-c operated cranes equipped with a mechanical load brake.

The control situation must also be taken into consideration. For instance, with a large capacity power-house crane, where exact inching of the loads is necessary, a brake with quick response in setting and releasing is required. This precludes certain types of operating mechanism on the a-c brakes. While the a-c solenoid is the fastest acting of any means so far presented, it has limited application to an electric brake, since the pull of the solenoid and its stroke is a determining factor of the maximum torque rating of the brake. Consequently, on heavy capacity power-house cranes, requiring large torque rated brakes it may be necessary to resort to two brakes in parallel in order to obtain the necessary torque rating. In such cases it is customary to mount one brake on the motor extension shaft and the other on either the motor coupling or the motor-coupling extension shaft. This permits the two brakes to be of the same size and torque rating, thus duplicating parts and minimizing spares.

Selection of the proper brake for the bridge drive can be made on the basis of a brake to provide at least 150 per cent retarding torque, based on the rated torque of the motor. Too large a bridge brake would be detrimental to the operation of the crane, as would also too small a brake. Modern practice dictates the use of an hydraulically operated brake for this purpose, rather than a mechanically operated brake which, because of its long linkage and drag-link connections will require close attention, both as to lubrication and maintenance.

The trolley motion for roller-bearing cranes should be equipped with a 50-per cent torque brake. Experience has shown that a 50-per cent torque brake of either the electric or constant-drag type will provide a gradual stopping action of the trolley under average load conditions within the rated capacity of the crane without undue swinging of the load.

Limit Switches

It must be remembered that the limit switch for the hoist motion of a crane is a safety device, and is not to be used as a constant stopping device for the upper travel. Selection is determined by the classification of the cranes, the hoisting speed and length of lift. A requisite of a good limit switch is that it be positive in action, its contacts must not freeze, and it must reset automatically upon lowering of the hook block.

Control

The selection of proper control for an overhead traveling crane requires more judgment based on experience than that of any other part of the crane. Among the requisites are good speed-regulating properties, a minimum of five steps of speed regulation, accessibility, ease of operation and ample protection against shorts and grounds. Moreover, it should be so mounted in the crane cab as not to obstruct the vision of the operator. The three fundamental types of control are manual, semi-magnetic and full magnetic for both a-c and d-c operation. Many users are now demanding full magnetic control which involves a higher initial cost but has the advantage of lower maintenance and greater ease of operation. However, where the manual type is selected for such service as in power houses, it is preferable that either the face-plate type or the drum type be used, providing the horsepower requirement for such control falls within the limiting factors. These factors are as follows: for d-c dynamic lowering hoist controllers, a maximum of 15 hp at 230 volts d c; for reversing service, such as is used on bridge and trolley drives, 40 hp at 230 volts d c; and for a-c reversing service, for hoist bridge and trolley motions, the hoist motion being used in conjunction with a mechanical load brake, 49 hp at 220 volts a c. If the horsepower requirements are beyond these limitations a semi-magnetic type of control should be used. The limiting factors in this case are 40 hp for hoist dynamic lowering service at 230 volts d c, and 50 hp reversing service for bridge and trolley travel at 230 volts d c. For alternating-current operation the semi-magnetic control is recommended up to 75 hp with either 220 or 440 volts for reversing service of hoist, bridge or trolley motion. For heavy duty the full magnetic type of control is recommended.

Variations from the foregoing are numerous. For instance, standby duty crane service for a power-house installation necessitates a very long lift, and with slow hoisting speeds, due consideration must be given to the adequacy of the mechanical load brake, as well as the proper selection of both motor and control equipment. It is also possible that a

crane for such service might be equipped with pendant rope, or selective push-button control for floor operation where operation is so infrequent as not to warrant a crane operator in the cab.

New Regulations Cover Special Purpose Coals

Because of the increasing need for military supplies and materials, Solid Fuels Administrator Ickes has announced that distribution of "special purpose" bituminous coal will be controlled to assure adequate supplies for essential war production industries in the 1945–1946 fuel year which starts April 1. He stated that requirements for these coals, which are vital to the manufacture of coke for steel and gas industries and certain other products required in making war materials, will be so great that it probably will be necessary to increase diversions begun last August from industries which use them chiefly for making steam.

A new regulation has been issued, as the first step in laying plans to make certain that the fuel is shipped in needed amounts to plants where its consumption will contribute directly to war production. This requires all industrial consumers of the special purpose coal to make their 1945–1946 contracts with suppliers before February 1. The contracts must be forwarded to the Solid Fuels Administration for War prior to February 10 for approval. From information to be supplied by consumers along with the contracts, the SFAW will determine the amount and sizes of special purpose coals a war plant or other consumer will require during the next fuel year. On the basis of the reported requirements additional coal may be provided to a consumer by specific direction, this being diverted if necessary from other industries which can use coals that are more plentiful.

Companies who own both mines producing special purpose coal and the plants where it is used are not required to file formal contracts between the mines and their consuming plants, but must submit information before February 10 showing the anticipated production of the captive mines and the use to which the tonnage will be put.

Energy Production and Fuel Consumption

Latest figures issued by the Federal Power Commission show that the electric energy produced for public use in November 1944 totaled 18,888,508,000 kwhr, a decrease of 1.7 per cent as compared with November 1943. However, for the twelve months ending November 30, 1944, the production was 227,866,830,000 kwhr, which represented an increase of 5.9 per cent over that for the twelve months ending November 30, 1943.

The capacity of generating plants in utility service in the United States is given as 50,234,657 kw.

Consumption of fuel by utility plants in November 1944 was 6,830,787 tons of bituminous coal, 289,744 tons of anthracite, 1,838,076 bbl of fuel oil, and 26,633,-241 mfc of natural gas. This last figure represents a 12 per cent decrease from the October consumption.

Middle East Oil Supply vs. Domestic Oil Policy

The President's action on January 10 in asking the Senate to return the Anglo-American oil agreement for revision to correct certain misunderstandings, revives interest in oil supply from the Middle East and its possible effect on our domestic market. It is therefore pertinent to review the opinion of Robert E. Wilson, President of Pan-American Petroleum & Transport Company, concerning this matter, as expressed before the New York Section, A.I.M.E. last November and later reported in *Mining and Metallurgy*. Mr. Wilson's remarks were in substance as follows:

> One of the most startling facts concerning the Middle East fields is that a total of 160 wildcat wells drilled have proved up reserves about as great as the entire proved reserves of the United States, namely, 20 million barrels. (As a wild guess, it probably took something like 50,000 wildcat wells to find ours.) This indicates that the Middle East fields are incomparably richer than those in this country.
>
> It is obvious that this oil is going to find an outlet, and in order to eliminate much disruption and waste, some form of international agreement should be effected.
>
> Logically, the Arabian areas would supply a larger portion of the European market in the future. This would tend to back up the stream of oil now going to Europe from the United States and Venezuela. It would mean a larger proportion of the Venezuelan oil coming to the United States. Incidentally, these changes would take place with no substantial increase in the amount of tanker haul required and with no great shifting of the price unless there were some international price war or some major change in import policy on the part of this Government.
>
> Oil import policy can constitute a serious problem. If we let imports come in too freely we will not hunt for oil here. Private industry will not enter aggressively into development of oil from shales and coal as long as crude prices remain about at present levels. It would seem that the sound thing to do would be to keep enough oil coming in so that there will be no lack for transportation or legitimate industry, but not so much as to prevent domestic oil prices from being high enough to keep our geologists and drillers hunting for oil; also, our chemical engineers interested in developing substitute sources of oil.
>
> The most serious and imminent danger to the future of the petroleum industry lies in any threat to the future of research and technology, which are indispensable multipliers of our natural resources. In this connection recent attacks on our patent system, by impractical theorists and faddists, point an effective way to super-sabotage the future. The only thing that can prevent our country from having abundant liquid fuel for many generations at reasonable prices, is interference with the free play of technology and competitive enterprise.

Turbine Notes

The General Electric Company, in its annual review of power generation, observes that, despite heavy demands on the production facilities of turbine manufacturers during 1940—covering more and more turbines for naval, maritime and mobile power applications—hundreds of thousands of kilowatt capacity were built for stationary power plants in this country, as well as some for export. Practically all were for installation where additional generating capacity was needed to meet demands of war industries.

The largest of the Schenectady-built turbine-generators installed during the year was that for the Twin Branch Station of the American Gas & Electric Company. It was an 85,000-kw cross-compound machine and the fifth of that size for this company. Other such units were to have been built, but to save manufacturing capacity for the war effort and to reduce the number of forgings and parts required, the designs were changed to 80,000-kw single-cylinder machines. With one exception, the larger turbine-generators supplied during the year were hydrogen-cooled and the majority were designed for rotative speeds of 3600 rpm.

Higher Steam Temperatures Now Possible

The Westinghouse Electric & Mfg. Company states that successful operation over two years with the 950-F, 125,000-kw turbine at Burlington Station and with the 950-F, 50,000-kw, 1600-psi topping unit at Sherman Creek Station in New York makes it possible to take the next step in initial temperature by going to 1000 F. A 50-deg rise in temperature of the inlet steam means a gain of nearly two per cent in the calculated overall plant efficiency.

Incidentally, the latter company announces a new type of blade construction to meet the need for stronger impulse blades in the high-pressure range. The root of each blade is shaped like an inverted U, and three blades are brazed together to form a solid segment which fits into circumferential grooves in the spindle. With the segments in position holes are drilled crosswise through the rotor and through the edges of two adjacent segments. Pins are then driven through the holes and the ends peened. The result is a tightly locked structure in which the areas carrying stress are positively known, which is something not always possible with multiple-fit blades.

Also, a new reaction blade that permits wide variation in speed with relatively small reduction in efficiency has been developed by Westinghouse. In sharp contrast to the blades with a relatively sharp forward edge, as commonly used, the new reaction blade looks in cross-section like a curved airplane wing, with its characteristic blunt leading edge. The maximum efficiency obtainable is practically the same as that of blades having sharper inlet edges, but the blunt-edge blade suffers much smaller depreciation of efficiency for off-peak relationship of blade and steam speeds. This is especially important in marine and some industrial applications where variable-speed turbines are used.

Army Engineers Design Floating Power House

Recent completion of the power barge "Electra," for the U. S. Army Engineer Corps, caused electrical engineers in the West to speculate on the potential post-war value of such mobile floating power plants for harbor and navigable river areas. Designed by the Army Engineers and built by General Engineering and Dry Dock Co., Alameda, Calif., this barge is capable of producing a power block of 6000 kva and can be towed to any desired water-front area.

As a post-war unit, it has been suggested that similar plants could be employed in cities providing harbor facilities as disaster or standby power stations. Depending upon the production demands in any harbor, this same unit could be used to supply additional power when a large block of electricity is needed for construction, ship loading or unloading. Although it has been said that it might not be practical to supply this power to shore transformers located more than a mile from the water's edge, engineers say such a barge could assist in equalizing the load demand on the utility company supplying the area, when necessary or as desired.

The "Electra" has eight 750-kva, 2400-volt, 3-phase, 60-cycle, 720-rpm Westinghouse generators driven by direct-connected Winton diesels of 1300 hp each. Power is fed through a unit switchgear, completely enclosed, to an outdoor-type substation mounted on the stern of the barge. This substation comprises three 2000-kva oil-insulated self-cooled step-up transformers, from 2400 volts primary to 12,000 volts secondary. The 12,000-volt power is transmitted from the outdoor switch house through a cable to the dredge or substation being fed by the barge.

Lubrication Engineers Form National Society

Lubrication engineers, representing prominent industrial and transportation companies and including educators, have organized the American Society of Lubrication Engineers with headquarters at 135 South La Salle Street, Chicago. While many papers and meetings on lubrication have occupied places on the programs of other engineering societies, lubrication engineers have long felt the need for a national organization pertaining directly to their profession. In carrying out this objective it is stated that there will be no conflict with the activities of other societies along this line.

Officers of the new society are C. E. Prichard, Republic Steel Company, president; J. C. Peebles, Illinois Institute of Technology, vice-president; B. H. Jennings, Northwestern University, secretary and treasurer. Directors include D. N. Norris, Inland Steel Company; I. L. Harper, Lehigh Valley Railroad; and D. E. Whitehead, Carnegie-Illinois Steel Co.

The first national convention has been scheduled for February 8 and 9 at the Stevens Hotel, Chicago.

Personals

Herbert B. Reynolds, until recently Superintendent of Motive Power of the I. R. T. Division of the New York City Transit System, has been given the duties of Superintendent of Power Generation for the entire system which includes the Interborough Rapid Transit, the Brooklyn-Manhattan Transit, and the Independent Subways. In this position he has charge of all the power stations, representing a combined capacity of 600,000 kw and an annual output of over 1,600,000,000 kwhrs.

Livingston W. Houston has been elected president of Rensselaer Polytechnic Institute, Troy, N. Y., which has the distinction of being the oldest engineering college in the United States. A mechanical engineering alumnus of this school, class of 1913, Mr. Houston has been associated with its administration for the past 13 years. He succeeds Dr. William O. Hotchkiss who retired.

Royal L. Meyer has been appointed Chief Engineer and Assistant Manager of the Steam Division of The Swartwout Company, Cleveland, O. Until recently Mr. Meyer was a partner of Vern E. Alden, consulting engineer, Chicago, and had previously spent 18 years with the Standard Oil Company of Indiana in power plant work.

Fred H. Hehemann, until recently assistant chief engineer of the Lunkenheimer Company, valve manufacturers, has been appointed chief engineer, succeeding J. J. Aull who retired on December 31 after nearly fifty years with the company. Mr. Hehemann has been with that organization since 1904.

David C. Prince, a vice president of General Electric Company has recently been placed in charge of the company's General Engineering Laboratory, the activities of which will be broadened to include the requirements of the entire company. Mr. Prince is a past president of the American Institute of Electrical Engineers and joined the General Electric Company shortly after graduation from the University of Illinois in 1912.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Corrosion

"Corrosion," a 54-page publication issued by The International Nickel Company, presents a comprehensive analysis of corrosion principles. The opening section explains how corrosion processes work, and discusses all the known factors that influence their action: acidity of solution, oxidizing agents, temperature, agitation, films, inhibitors, surface condition, stress, heat treatment, welding, concentration cells, and galvanic action. These discussions are illustrated with graphs, drawings and tables. A detailed review of testing methods follows, and the applicability of Monel, nickel and Inconel in various corrosive media is analyzed in the closing section. Tables list nearly 500 typical corrosives in which these alloys have been successfully used, and report the results of more than 120 specific tests under varied conditions in 44 common corrosive agents.

Flow Meters

Cochrane tilting U-Tube mechanical type meter is illustrated and described in an 8-page publication (No. 3010-31). Three fundamental features are incorporated in this high torque mechanical meter: (1) flow measurement by response to difference in pressure by a mercury seal in a U-Tube; (2) weighing mass by means of a beam balance; and (3) the use of torsion tubes as the scientific solution of the stuffing box problem.

Oil Burners

A new 4-page bulletin (No. 802), describing the Peabody Type M Oil Burner, has just been prepared by the Peabody Engineering Corporation. It describes and illustrates the mechanical and operating features of the burner, for natural or forced-draft operation and for use with mechanical, wide-range mechanical or steam atomizers.

Measuring Instruments, Telemeters and Controls

Leeds & Northrup Company has issued a new 28-page publication (ENT-7a) which describes all its measuring instruments, telemeters and controls for regulating power plant processes. The equipments are grouped according to their applications. Under "Electrical Generation" are those for measuring load telemetering and totalizing, frequency and time deviation, kvar, voltage and generator temperatures. Under "Generation of Steam, Hydro and Diesel Power," those for measuring gas analysis, smoke density, speed, electrolytic conductivity and boiler temperatures, liquid level and hydro temperatures, and engine temperatures. Also described are: the Centrimax Flowmeter; the L & N Load-Frequency Control; Metermax Combustion control—a pneumatic-electric system; and Type P Combustion Control—and all-electric system.

Steam Condensers

C. H. Wheeler Manufacturing Co. has issued a folder featuring its line of Dual Bank Steam Condensers. It illustrates this company's condenser development since 1916 and also its latest standard and low-head types of surface condensers.

Another 4-page folder issued by the same company features standard and special type Tubejet Vacuum Pumps. Tubejet can be used with almost any type of steam condenser.

Thermocouple Data Book

A new enlarged edition of its Thermocouple Data Book and Catalog has been issued by Wheelco Instruments Company. Designated Bulletin S2-5 and containing 40 pages, the catalog describes products, gives prices and offers recommendations for thermocouple users. It gives data helpful in selection of thermocouples, lead wire, protecting tubes, heads and insulators. Also included are millivolt tables on the various types of thermocouples, temperature conversion tables, tables on wire resistance and on pipe and wire sizes, and a fraction-decimal equivalent chart.

Water Flow in Pipes

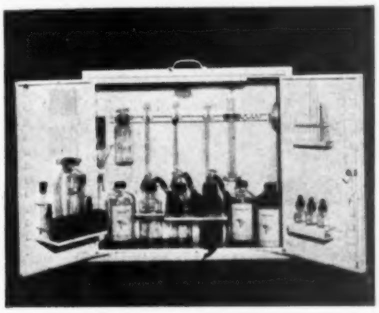
Grinnell Company has issued a Universal Calculator for flow of water in pipes, designed by T. Francis O'Connor to show simultaneously all hydraulic factors usually required in water works problems. This slide calculator gives readings for: length, size and coefficient of pipe; flow in gpm; velocity; total pressure loss in pounds (and feet) for given pipe length. No matter where the slide is set, all figures visible in the windows of the Calculator are true (based on the Hazen & Williams formula) simultaneously.

NEW EQUIPMENT

Water Testing Apparatus

The Bird-Archer Company announces a new Multitest cabinet for the testing of water samples. It is compact (24 × 22 × 11 in.) and is ingeniously devised to accommodate any one or all of the following tests: Hardness, Alkalinity, Chloride, Phosphate, pH, Sulphite, Sulphate and Dissolved Oxygen. The testing equipment can be rearranged at will.

It is equipped with glareless fluorescent lighting, so that the most delicate end-point may be seen, and specially designed titration tables help to eliminate any possible splashing of sample.



The illustration above shows cabinet with testing equipment for Hardness, Alkalinity, Chlorides and Soluble Phosphate.

Ash-Handling System

New design features in the Beaumont "Vac-Veyor" pneumatic ash-handling system are announced by the Beaumont Birch Company. Ash receiver, separator and air washer are now combined in one unit on top of the silo. The mixture of ash, steam and air enters the receiver tangentially, and centrifugal action throws heavy ash particles out of the stream into the silo while baffle plates in the separator (and reduced steam-air velocities) cause the light ash to settle into the silo through a conical baffle. The steam-air mixture then passes to the washer where any remaining light fly ash can be washed away through 4-in. soil pipe. The manufacturer states that, in most installations, the use of sprays in the air washer is unnecessary.

Electronic Temperature Recorder–Controller

An Electronic Type Resistance Thermometer suitable for indicating, recording and controlling temperatures between −100 F and 1000 F is announced by Bailey Meter Company. This recorder operates on the null balance principle and provides instantaneous balancing action by electronic detection and control. Indicating recording and controlling mechanisms are all driven by the same reversible electric motor which adjusts the slide resistance to balance the measuring bridge. As many as four recording pens may be used, each one being provided with its own continuously connected electronic control unit and measuring bridge.

Bailey Air-Operated Control, Electronic Control or contacts for on-off electric control may be provided for as many as two temperatures by the multiple-pen instrument. Alarm contacts, operated by an adjustable cam, may be provided for any or all of the recorder units.

Temperature measuring circuits may be arranged to calculate the sum, difference and ratio of temperatures.

Forced-Draft Blower

Westinghouse Electric & Mfg. Company announces a vertically-operated steam-driven blower for cargo ship service. No governor is used because speed is limited by the blower, the load of which increases as the speed is cubed. Overspeed is thus eliminated. No oil cooler is used (and therefore no water connections), and only one steam gland is required as both bearings are placed below the turbine element. This also permits the removal of the entire rotating element (with bearings) as a unit assembly. Furthermore, by a unique arrangement of oil chambers, no packing is needed to hold oil.

Fan-Cooled Worm Gear

Forced air-cooling, as employed in the new De Laval Fan-Cooled Worm Gear Speed Reducer, is claimed to remove the heat of high-speed operation so effectively that the capacity of the gear is doubled for practically all ratios and sizes at 1750 rpm. This permits the use of smaller, lighter and less expensive speed reducers without sacrifice of efficiency or durability.

As can be seen from the illustration, a fan mounted on the worm shaft draws air at high velocity over and around heat dissipating ribs upon the air side of the oil reservoir housing the gearing. The use of a double wall increases the effectiveness of the cooling by confining the cooling air to the housing and thus securing the close air-to-metal contact necessary for maximum heat transfer.

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